APPENDIX 5-2

TASK 5.3.4.7.2 EVALUATION OF PMP/PMF AND DAMBRK SUMMARY TECHNICAL MEMORANDUM

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Task 5.3.4.7.2 Evaluation of PMP/PMF and DAMBRK Summary Technical Memorandum

To: Distribution

From: Jim Schlaman

1. OBJECTIVE

This memorandum summarizes the development of the US Army Corps of Engineers (USACE) HEC-RAS dam breach model of the EAA Reservoir A-1. The overall objectives of this memorandum are as follows:

- To determine the hazard classification of the EAA Reservoir A-1.
- To determine the characteristics of a Probable Maximum Precipitation (PMP) and Sunny Day dam failure of the EAA Reservoir A-1 embankment
- To determine the extents and characteristics of the floodwave from an EAA A-1 embankment breach and produce flood hazard mapping for an Emergency Action Plan

Output that will be generated includes the following:

- Hazard class determination for the A-1 reservoir embankment.
- Dam breach characteristics such as breach width and time of failure.
- Inundation mapping including peak water surface elevation, peak flowrate, floodwave arrival time, and time to peak.

2. EVALUATION CONDITIONS

Typical conditions modeled in dam breach studies include the evaluation of PMP and Sunny Day breach events. Safety is of top priority when considering dam breach impacts, therefore conservative assumptions are used. Guidelines for developing PMP and Sunny Day breach design conditions can be found in various documents and are referenced at the end of this memorandum.

The two dam breach conditions considered were:

- PMP Dam Breach (PMP Scenario 1): As identified in the *Interim Summary Technical Memorandum* (Burgi et al. 2005), the PMP across the EAA Reservoir A-1 was 54 inches (4.5 ft) of rain. Since the normal pool depth of the EAA Reservoir A-1 will be about 12 ft, the PMP depth is considered to be 12 + 4.5 or 16.5 ft of depth. The PMP conditions outside of the reservoir will be detailed further in Section 2.1

- Sunny Day Dam Breach (Sunny Day Scenario 1): The Sunny Day breach from the EAA Reservoir A-1 will be considered to occur when the lake is at a normal pool depth of about 12 ft. The Sunny Day conditions outside of the reservoir will be detailed further in Section 2.2.

Additional evaluation conditions were generated for the sensitivity analysis performed herein. They appear in the results section to illustrate the sensitivity of the model results to the input parameters.

To determine the breach characteristics of the A-1 PMP and Sunny Day embankment failures, the preferred embankment cross section identified in the *Embankment Technical Memorandum* was considered (Molyneux et al. 2005). It is shown as Figure 1. Note that it illustrates the placement of rock fill on the interior face of the embankment, which will help resist erosion and scour during a breach event. The methodology of developing the breach width and time of failure for each breach event is described in Section 5.1.

2.1 Evaluation Condition 1: PMP Dam Breach

For normal PMP dam breach evaluations, the PMP storm is routed through the dam of interest, and the breach event is considered to occur when the flood stage in the reservoir reaches its maximum. However, the EAA Reservoir A-1 has not been designed to have an uncontrolled spillway and therefore releases from the reservoir would only occur if the gate structures were operating. Furthermore, since the reservoir does not have a contributing watershed, the volume of water from a PMP storm is simply the depth of the storm itself added to the initial water surface elevation (WSE) in the reservoir. The most conservative condition assumes that the dam breach would occur when the surcharge is highest; that is, without gate or spillway releases. Utilizing this assumption, the PMP dam breach depth in the reservoir when the breach begins is as follows:

EAA Reservoir A-1 PMP Depth

Normal Pool Depth	12 ft
PMP Depth	4.5 ft
Total A-1 Depth	16.5 ft

Design Criteria Memorandum 2 (Haapala et al., 2005b) defined guidance for developing the antecedent water depth at the start of the PMP breach. It included a provision for a 30% PMP storm followed by 3 days of dry weather, followed by the PMP. The additional depth of rain (30% PMP, 1.35 ft) is routed during the 3 dry days to determine the initial water depth at the beginning of the PMP storm. However, at the CCM, held by the South Florida Water Management District (SFWMD) on June 20-22, 2005, this methodology was discussed. It was determined that the 30% storm could be completely discharged through STA 3/4 during the 3 dry weather days. Therefore, the additional 30% PMP (1.35 ft) was not added to the water surface elevation of the lake when analyzing the PMP dam breach.

In addition to antecedent water depth, another important set of assumptions is the condition of the downstream channel when the PMP breach occurs. Typically, a storm in the magnitude of a 100-year event is considered to be occurring downstream. However, the EAA Reservoir A-1 does not have a true “downstream” area, and since the embankment is perched on all sides, the breach can occur on any side. The EAA Reservoir A-1 configuration also presents another challenge: a PMP can occur across just the EAA Reservoir A-1 or across the EAA region (defined as the NNR canal and Miami Canal Watersheds), as was considered in the *Interim Summary Technical Memorandum* (Burgi et al. 2005). A PMP across the entire EAA region was demonstrated to be 42.71 (3.5 ft) inches of rain.

Moreover, during a regional PMP event that could drop 3.5 ft of rain, many of the road and canal embankments which could contain the dam breach floodwave, would be submerged or partially submerged. For example, notice on both Figures 2 and 3 that the minimum embankment elevation along the Bolles and Cross Canals ranges from 11.2 ft (NAVD88) to 11.62 ft (NAVD88) as obtained from the hydraulic model detailed in the *Hydraulic Model Summary Technical Memorandum* (Means et al. 2005). The *Hydraulic Model Summary Technical Memorandum* also demonstrates that the surrounding ground surface around the Bolles and Cross Canals is nearly identical to that of the reservoir (~8.6 ft, NAVD88). If 3.5 ft of rain were to fall, these embankments would be submerged. It therefore seems likely that in the event of a regional PMP, the embankments will not be sufficient barriers to stop to the floodwave propagation, and the downstream conditions are assumed to be flooded to the extent that the canal and road embankment do not interfere with the floodwave propagation.

Lastly, it should be noted that during the regional PMP event, the hydraulic gradient from the reservoir to the surrounding land remains at about 12 ft because the reservoir receives the same depth of water that the surrounding land receives. To investigate the sensitivity of the model to these assumptions, several runs were made to bracket the dam breach solution. However, to be most conservative, the final results presented for the PMP dam breach, shown in Figure 5, will include a reservoir pool depth of 16.5 ft at the beginning of the breach event (not 12 ft as in the case of the regional PMP breach event), and will ignore the downstream canal and road embankments due to submergence. Because tailwater assumptions affect the results of the dam breach, see Sections 5.2.1-5.2.7 for a description of the tailwater assumptions made for each PMP run included for the sensitivity analysis. To maintain conservative results, the tailwater condition for the design condition chosen to illustrate the PMP breach illustrated by Figure 5 was assumed to not impact the hydraulic results (i.e. PMP depth of 16.5 ft, tailwater hydraulic effects were ignored, but the tailwater submergence effects were included).

2.2 Evaluation Condition 2: Sunny Day Dam Breach

The Sunny Day dam breach is typically regarded as the more dangerous breach event because it occurs when the population is least expecting it and the incremental downstream impacts are greater. Dam breach studies and corresponding inundation mapping are typically delineated until the floodwave incremental depth is less than 2 ft, as defined in FERC guidelines (FERC, 1993). Interestingly, the Sunny Day event can often be delineated further because there is no antecedent flooding condition limiting the amount of incremental change. However, in the case of the EAA Reservoir A-1, the incremental impacts of a Sunny Day dam breach will be equal to or less than that of a PMP breach (downstream region is flat with no channelization, therefore the initial head differential is driving force behind the incremental impacts) while the aerial extents of the PMP breach will be greater. Therefore, the main concern with the Sunny Day dam breach is not the extent of flooding but rather the unexpectedness of the breach to the surrounding population. The Sunny Day EAA Reservoir A-1 antecedent condition is assumed to be the normal pool depth of about 12 ft.

Downstream antecedent conditions for the Sunny Day dam breach event are critical in determining the extent of the floodwave propagation. If the ground is not considered inundated, then the regions canal and road embankments will be major barriers that may contain the flood breach. However, if it is assumed that the Sunny Day dam breach occurred while the surrounding lands were completely or partially inundated, then the embankments can possibly be ignored. For this study, the assumption will be that the Sunny Day dam breach downstream conditions are dry and that the road/canal embankments may be capable of containing the floodwave.

3. MODEL CONFIGURATION

The unsteady flow HEC-RAS model Version 3.1.3 was selected to simulate a potential dam breach from the EAA Reservoir A-1. The model was configured with four cross sections upstream from the embankment (simulated as an inline weir) to approximate the volume in the reservoir at varying depths. The breach progression was set to occur linearly, with the base of the breach reaching the bottom of the embankment (Depth = 0 ft, NAVD Elevation = 8.6 ft). The side slopes of the internal breach opening were set to 0.5:1 as suggested by *Selecting and Accommodating Inflow Design Floods for Dams* (FERC, 1993). The downstream control was set to normal depth with a slope of 0.0001.

3.1 PMP Dam Breach Model Configuration

For the PMP dam breach model used to generate the flood hazard mapping in this report, the downstream region impacted by the floodwave was assumed to be a flat surface extending 200,000 ft away from the reservoir embankment at a 3:1 expansion ratio. No canal or road embankments were inserted into the model because it was assumed that they were submerged at the time of the PMP dam breach. A Manning’s coefficient of 0.03 was used for the entire extent of the downstream reach. Although this number initially appears to be lower than what would be used for the type of vegetation present, the downstream area is assumed to be inundated and the floodwave will be traveling across standing water, not a rough ground surface. Therefore, a conservative Manning’s value of 0.03 was chosen to model this situation.

Another dam breach configuration (PMP Scenario 4) was set up to investigate the specific situation of the dam breach occurring on the southeast side of the reservoir, which may be contained between Stormwater Treatment Area (STA) 3/4 and Compartment B embankments. The width of the downstream channel from the breach was assumed to be 600 ft wide for the first 28,000 ft away from the reservoir embankment. Upon reaching the southern portion of US 27 and the STA 3/4 embankment (See Figure 4), the model was allowed to expand at a 3:1 ratio. This specific model configuration was made to investigate the effects that channelization between STA embankments would have on the dam breach depth and flood extents. Although assuming the flow would be channelized between the STA embankments is very conservative, review of the results showed that the solutions provided some additional insight into the extreme events.

3.2 Sunny Day Dam Breach Model Configuration

The Sunny Day dam breach model was set up similarly to the PMP dam breach model, with the major difference being that the Sunny Day dam breach model assumed that the downstream reach was not inundated. Therefore, canal and road embankment heights were investigated to determine the extent of the floodwave. Rather than placing these berms into the HEC-RAS model, the elevations of the important embankments were compared to the energy gradeline from the Sunny Day dam breach model. If the breach results showed that the floodwave had enough energy to overtop the low point of the canal, then the floodwave was considered to continue to spread until reaching the next embankment, where the analysis was performed again. The downstream Manning's value for the sunny day breach was again chosen to be 0.03. Although, the assumption is that the downstream area is not inundated, there still may be some standing water from irrigation or other sources which sufficiently submerges the area. Since this assumption provides a conservative evaluation, it was left unchanged.

4. MODEL CALIBRATION, VERIFICATION AND RELIABILITY

A variety of dynamic models are available to simulate a dam breach, including: NWS-DAMBRK, NWS-FLDWAV, MIKE 21, MIKE-11, MIKE FLOOD and HEC-RAS. For many years, the US standard for performing dam breach investigations was NWS-DAMBRK which has subsequently been replaced by NWS-FLDWAV (NOAA, 1991). However, with the inclusion of UNET (dynamic hydraulic routing program) into the HEC-RAS software package, reliable dam breach estimates are now available using HEC-RAS (USACE, 2002). Multiple studies have been performed comparing the output from HEC-RAS versus the output from DAMBRK/FLDWAV and the determination is that the programs produce similar results (Gee, 2004) (Baker, 2003). Since data is not available to calibrate, the results should be reviewed for appropriateness while a sensitivity analysis should be performed to determine which variables affect the results the most. In order to study the EAA Reservoir A-1 breach, a sensitivity analysis was performed to show the effects of changing one or more variables. The results of the sensitivity analysis will be shown in Section 5.

5. RESULTS

The three main objectives of this report were to:

- Determine the hazard classification of the EAA Reservoir A-1
- Identify breach characteristics from a potential PMP and Sunny Day A-1 embankment breach
- Generate inundation mapping that details peak water surface elevation, peak flowrate, floodwave arrival time, time to peak, etc. around the EAA Reservoir A-1

The Hazard Classification of the EAA Reservoir A-1 embankment and reservoir has been determined to be high hazard, as specified in both *Selecting and Accommodating Inflow Design Floods for Dams* (FERC 1993) and *Design Criteria Memorandum -1: Hazard Potential Classification* (Haapala et al. 2005a) guidelines. US 27 carries a large traffic volume and will be located directly adjacent to the eastern A-1 Embankment (see Figure 4). A Direct Loss of Life is imminent if the embankment fails, especially if the failure were to occur on the eastern side. The potential depth and velocity of a floodwave across US 27 is greater than 10 ft and 10 ft/s respectively (from either a Sunny Day or PMP breach). Furthermore, US 27 is an evacuation route for residents of South Florida, so not only is an A-1 embankment failure a direct threat to motorists, a dam failure would inhibit a major evacuation route for the surrounding population. Risks to population centers around the Everglades Agricultural Area (EAA) during an A-1 embankment failure are provided in detail in Sections 5.1 and 5.2; the towns of Belle Glade, and South Bay, FL are considered to be at risk from either breach event.

The finished floor of pump station G-370 is at elevation 28.27 ft (NAVD88) and therefore will not be inundated by a dam failure. This can be assured because the maximum potential energy in the EAA Reservoir A-1 equals 25.1 ft (NAVD88), as calculated by adding the 8.6 ft (bottom of reservoir, NAVD88) plus the PMP depth (16.5 ft), which is still less than the pump station floor elevation. However, South Florida Water Management District (District) employees may be in an adjacent low lying area at the time of the breach. Therefore, along with the danger to the traffic on US 27, local farmers and district employees stationed around the G370 and other pump stations will be at risk during an EAA Reservoir A-1 breach. See Figure 4 for site layout.

A sensitivity analysis was performed to illustrate the effects of changing the input parameters on the breach characteristics and results. However, only the most appropriate of dam breach scenarios was chosen to produce the inundation mapping seen in Figures 5 and 6. The goal of the inundation mapping is to illustrate the area that needs to be evacuated in case an A-1 dam breach occurs. The inundation mapping will be used in an overall Emergency Action Plan (EAP) for the EAA Reservoir A-1 to be prepared at a later date. In general, Emergency Action Plans detail an extensive set of contingency plans in case a dam breach was to occur. Since safety is the main reason Emergency Action Plans are created, it is common practice to be conservative in the interpretation of the inundation mapping presented. If a population area is adjacent to an inundated area, it might be the determination of the Emergency Action Plan to evacuate the area even though the flood inundation mapping does not indicate a direct threat. Knowing this, the inundation mapping extents prepared herein are conservative and include communities which the HEC-RAS model either showed were in the direct path of a floodwave or were close enough to the floodwave threat to justify an evacuation. Further interpretations of risks to surrounding population centers not shown to be in danger in this memorandum may be necessary during the preparation of the Emergency Action Plan.

5.1 Dam Breach Parameters Selection Methodology

The *Design Criteria Memorandum 1* (DCM 1) specified a methodology in estimating the breach width from CERP impoundments (Happala et al. 2005a). The DCM 1 guidance was partially obtained from dam breach recommendations made by the *Dam Break Inundation Analysis and Downstream Hazard Classification* written by the State of Washington Department of Ecology (Washington State Department of Ecology, 1992). The following equations were specified in those documents to estimate the dam breach width of a cohesionless embankment fill:

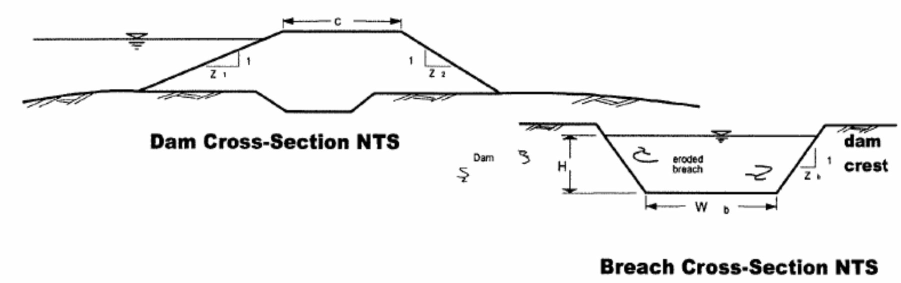
$$V_m = 3.75 * (V_w * H)^{0.77}$$

where:

V_m = Volume of material in breach (cubic yards) that is eroded

V_w = Volume of water stored in the reservoir (acre-feet) at the water surface elevation under consideration

H = Height of water (feet) over the base elevation of the breach



The above relationship estimates the breach volume which can be related through the cross sectional area of the embankment to the breach width. For a trapezoidal breach with side-slopes of (Z_b:1):

$$W_b = \frac{27V_m - H^2(CZ_b + HZ_bZ_3/3)}{H(C + HZ_3/2)}$$

where:

W_b = Width of breach (ft) at base elevation of breach

C = Crest width of dam (ft)

$Z_3 = Z_1 + Z_2$ and

Z_1 = Slope (Z_1:1) of interior face of dam

Z_2 = Slope (Z_2:1) of exterior slope of dam

Figure 1 shows the embankment considered in this analysis. Values not shown in that figure include a proposed dam height of about 26 ft above caprock, a top width of 12 ft, and interior and exterior embankment slopes of 3:1. Interpreting the guidance literally, the volume of material eroded by the breach (Vm) if the EAA Reservoir A-1 was at a normal pool depth of about 12 ft, equating to approximately 190,000 ac-ft of water, is approximately 295,000 yds^3. Other calculations can be made by utilizing the stage versus storage information of the reservoir. Once the Vm is determined, the width of breach (Wb) can be calculated. H is defined as the "Height of water (feet) over the base elevation of the breach" in the guidance. If this value is used for the Wb calculation, the breach width is calculated to be 13,800 ft wide. However, the intent of the authors was more likely to calculate the cross-sectional area of the embankment to determine the width of the breach. This means that "H" needed to be redefined as the height of the embankment rather than the height of water for the Wb calculation. Utilizing this "correction," the breach width is calculated to be 3,400 ft. Furthermore, in the future, the EAA Reservoir A-1 may be combined with the A-2 compartment, to make a larger reservoir with 360,000 ac-ft of storage at about 12 ft of depth. However, the reservoir may have a gate structure separating the A-1 and A-2 compartments so a breach of the EAA Reservoir A-1 would only drain that compartments volume. Because the A-1 compartment is bigger than the A-2 compartment, dam breach results from the A-1 compartment will provide a slightly conservative estimate of the dam breach results from the A-2 compartment.

In addition to the DCM-1 guidance and State of Washington guidance, the Federal Energy Regulatory Commission (FERC, 1993) has guidelines for developing the breach width. A typical FERC value for a breach of the A-1 embankment would be that it is 5 times as wide as the embankment is tall. Therefore, the breach would be about 130 ft in width.

Given the wide variety of breach widths that the various methodologies produced, it was determined that a series of dam breach scenarios would be run and the results checked for reasonability. When the output from the breach made sense with the assumed breach conditions, then it was considered to be a valid run. Utilizing this method, over 80 dam breach runs were made for the EAA Reservoir A-1 to select the most appropriate breach parameters. The logic for selecting appropriate dam breach runs was as follows:

- A breach width was chosen.
- A failure time was selected which equated to a reasonable average failure speed (~0.05 ft/s).
- The model was run with the combination of variables selected in 1 and 2.
- The results of the scenarios were analyzed including the reservoir depth and outflow velocity at the end of the assumed failure time.
- Realistic scenarios were identified by choosing those which produced outflow velocities near 6 ft/s (the lower bound of water velocity thought to scour the rock fill in the A-1 embankment) and reservoir elevations that were significantly drawndown from starting conditions.
- Based upon scenarios that were deemed reasonable in 5, further runs were made focusing on the reasonable range of solutions.

Although many scenarios were modeled, for the sake of clarity, the entire set of runs is not presented within this memo. They can be viewed in Appendix 5-3. However, scenarios that helped define the HEC-RAS models sensitivity have been included within this section.

5.2 PMP Dam Breach Results

Seven different scenarios are presented herein describing the PMP dam breach event of the A-1 embankment. Scenario 1 was chosen as the most appropriate dam breach run and is the basis for the PMP inundation map presented in Figure 5. The remaining runs, Scenarios 2-7 results, have been presented herein to show the sensitivity of the model to the input parameters. The following describes the PMP scenarios and their assumptions and results.

5.2.1 PMP Scenario 1 Description

The initial water depth in the EAA Reservoir A-1 at the beginning of the PMP breach event was 16.5 ft. This value was determined by summing the normal pool depth of about 12 ft and the PMP depth of 4.5 ft. No reservoir routing was considered. A breach width of 2,000 ft and failure time of 11.1 hours were developed utilizing the methodology presented in Section 5.1. No downstream controls such as road/canal embankments were considered because it was assumed that the adjacent landscape was inundated during the PMP event. The tailwater was assumed to submerge road and canal embankments which could contain the floodwave, but the hydraulic effects were not considered to maintain a conservative approach (Initial condition was set to 16.5 ft of depth). The expansion rate at which the water expands from the dam breach was set to 3:1, which is a reasonable expansion ratio and falls within guidelines presented in HEC-RAS guidance (USACE, 2002). The results of this scenario, shown in Table 1, were determined to be the most applicable for simulating a PMP dam breach and are the basis for the Inundation Mapping shown in Figure 5.

Given that the PMP Scenario 1 is driving the Inundation Mapping seen in Figure 5, it is important to closely examine the results. The dam breach model has identified that the towns of South Bay and Belle Glade, FL are at risk due to a PMP breach at the EAA Reservoir A-1, as defined by the 2-ft incremental increase FERC guideline, (FERC, 2003). They are located approximately 11.6 miles (61,200 ft) to the north of the EAA Reservoir A-1, but as Table 1 shows, the 2-ft floodwave is expected to travel approximately 80,000 ft to the north. Additionally, a major portion of US 27 will be impacted (See Figure 5), but no other major arterial roads appear to be at risk. The estimated floodwave arrival time at these towns is approximately 11 hours.

5.2.2 PMP Scenario 2 Description

This scenario is comparable to PMP Scenario 1 detailed in Section 5.2.1, except that the initial water depth in the reservoir was 12 ft. During a regional PMP event, the reservoir and surrounding landscape will receive the same depth of rain and be equally inundated. Therefore, the hydraulic gradient from the reservoir to the outside region is assumed to remain at a constant 12 ft of head. No downstream controls or road/embankments were considered because these structures could be submerged when the breach event occurs. The tailwater was assumed to submerge road and canal embankments and the hydraulic effects were considered (i.e. 12 ft depth initial condition rather than 16.5 ft depth initial condition). Notice that the breach width developed was 1,500 ft instead of 2,000 ft wide as in PMP Scenario 1. Utilizing the methodology presented in Section 5.1, the width of the breach should be smaller than PMP Scenario 1 because there is less head in the reservoir, which then reduces the outflow velocity and scouring potential of the flood flow. This scenario was included for informational purposes only and was not used to produce the inundation mapping. However, one should note that the extents of the floodwave from this breach event still reach the outskirts of the South Bay and Belle Glade, FL. This indicates that although this scenario's results are less conservative, the floodwave still has the capability to impact these cites.

5.2.3 PMP Scenario 3 Description

Due to the terrorist events of September 11, 2001, attention has been given to dam failures which are not naturally created. Therefore, this scenario addressed these concerns. As a means of providing a sensitivity analysis, this run is comparable to PMP Scenario 1 except that the failure time has been changed from 11.1 hours to 1 hour. This demonstrates the sensitivity of the results to changing this parameter. As one can see in Table 1, the maximum outflow is increased dramatically, but the extents of the 2-ft floodwave remain the same. Other impacts are that the arrival time of the floodwave will be four hours quicker than a floodwave in which the breach opening progresses at a “natural” rate.

5.2.4 PMP Scenario 4 Description

This scenario investigates the possibility that the breach of the A-1 embankment occurs near the southeast corner of the reservoir. With the addition of the STA B embankments on the east side of US 27 (See Figure 4) as well as the existing STA 3/4 embankments, there was concern that flow could be channelized between these two structures and increase the extents of flooding. Realistically, the embankments of STA 3/4 and proposed STA B are not sufficient in size to completely contain the floodwave unless they are increased in height. However, a conservative assumption is to assume that everything is contained between them and to review the results. It becomes apparent when restricting the dam breach conveyance area between these two embankments, estimated to be 600 ft apart, that the width of the conveyance area is narrow enough to choke the flow from the breach. This implies that although sufficient volume of water is contained in the A-1 embankment to open a breach width of ~2,000 ft, as shown in Section 5.2.1, that the channelized flow will create enough backwater effects to limit the outflow from the dam breach and reduce floodwave extents. It was determined from this analysis that unless significant alterations are made to the locations (Area between STA embankments widened) and heights of the STA 3/4 embankments and STA B embankments increased, the concern of channelization is not valid. Tailwater assumptions for the run were assumed to be the same is in PMP Scenario 1. Realistically, the water depth from a floodwave across US 27 is deeper near the A-1 embankment because of the effect of channelization, however the extents of this channelized flow is not greater than the PMP Scenario 1 which was allowed to expand at a 3:1 ratio in the downstream reach.

5.2.5 PMP Scenario 5 Description

This scenario demonstrates the sensitivity of the HEC-RAS dam breach model to changing the downstream expansion ratio of the floodwave. Rather than a 3:1 expansion ratio used in Scenario 1, a 2:1 ratio was used. As one can see in Table 1, this reduces the extents of the dam breach floodwave. However, this expansion ratio was ultimately considered not to be conservative enough for this analysis.

5.2.6 PMP Scenario 6 Description

This scenario demonstrates the sensitivity of the HEC-RAS dam breach model to changing the downstream expansion ratio of the floodwave. Rather than a 3:1 expansion ratio used in Scenario 1, a 4:1 ratio was used. As one can see in Table 1, this increases the extents of the perceived dam breach floodwave. However, this expansion ratio is typically used for jets of water expanding from an opening and it was ultimately considered to be overly conservative for this analysis.

5.2.7 PMP Scenario 7 Description

This scenario demonstrates the sensitivity of the HEC-RAS dam breach model to changing the Manning's coefficient in the downstream reach from 0.03 to 0.1. This scenario is identical to PMP Scenario 1, except for the Manning's number change. Although the floodwave velocity is much slower, the extents of the 2 ft floodwave are still very comparable to the others utilizing a lower Manning's value. The floodwave arrival time at South Day, FL is increased dramatically to 20 hours.

5.3 Sunny Day Breach

The initial water depth in the EAA Reservoir A-1 was set to 12-ft (normal pool depth) at the beginning of the breach simulation. To remain conservative, the Manning's number of the downstream HEC-RAS reach for the Sunny Day reach was left at 0.03. This is a conservative assumption, however standing water, even in a sunny day situation, is possible and would make a slicker surface. However, in contrast to the PMP scenarios discussed previously, downstream canal and road embankments were considered to be fully exposed. The tailwater was assumed not to inundate the surrounding region and was not considered hydraulically. If the energy grade line of the floodwave was enough to overtop the embankments in consideration, the floodwave was assumed to have breached the embankment and remain fully intact. A sensitivity analysis of the Sunny Day breach scenario was not considered necessary because the same effects as discussed in Section 5.2 would occur.

5.3.1 Sunny Day Scenario 1

Table 2 and Figure 6 demonstrate the results of the Sunny Day A-1 embankment breach. A discussion of the results is more difficult when considering this breach event because the downstream region was not considered to be inundated. The events of the 2-ft floodwave shown in Figure 6 were determined by investigating the elevation of the embankments around major canals and highways and determining if the energy of the breach event could overtop these structures. If the floodwave could not overtop the structures, the floodwave was assumed to be contained. Elevation information for the canal embankments was obtained from the HEC-RAS model detailed in Appendix 6-8 and SFWMD data. Of note, the Bolles and Cross Canal appears to have several embankment sections that are low enough for the approaching floodwave to overtop. Therefore, the towns of South Bay and Belle Glade, FL will be affected by a Sunny Day breach at the reservoir.

5.4 Comparison of Results

In all cases, the aerial extents of the PMP breach were determined to be greater than the Sunny Day breach. See Figures 5 and 6 for a pictorial representation of the results and Tables 1 and 2 for a written representation of the results.

5.5 Recommended Design Conditions

As discussed previously, a Sunny Day breach typically produces a greater incremental threat than the PMP breach. However, for the A-1 Reservoir, the PMP breach produces a greater threat because road and canal embankments cannot contain the floodwave and because the initial driving head of the PMP breach is greater than that of the Sunny Day breach. As a result, the aerial extent of flooding from the PMP breach is greater than the Sunny Day breach extents and the incremental impacts are equal to or greater.

Emergency Action Plans need to be clear and to the point. The downstream area in the EAA has the capacity to be inundated without a storm event (i.e. farms flooding the fields). Furthermore, the region can be inundated for several weeks after a large storm event as demonstrated in Appendix 5-1. It should not be assumed that the reservoir is at normal pool elevation when conditions are “Sunny” outside. Therefore, it is the determination of Black & Veatch that the PMP inundation limits shown in Figure 6 should be used to determine the evacuation area in a future Emergency Action Plan. This will lead to a clear understanding of the evacuation zone downstream from the A-1 reservoir that needs to be established and reduces the chance that any misjudgments are made when choosing the type of breach event that might have occurred at the A-1 reservoir.

6. SUMMARY AND CONCLUSIONS

Inundated areas considered to be a life hazard by FERC guidelines (2-ft deep floodwave) from a dam breach of the EAA Reservoir A-1 embankment stretch approximately 80,000 ft away from the reservoir embankment during the PMP breach. Because the EAA Reservoir A-1 embankment is perched on all sides, contouring the floodwave depth, as seen in Figures 5 and 6, was determined to be the best method to visualize the effects. Significantly impacted areas from a PMP dam breach of the EAA Reservoir A-1 include US 27 and the cities of South Bay and Belle Grade, FL. No other major travel arteries or population centers were deemed to be at risk if a PMP failure were to occur. Sunny Day breach extents are shown in Figure 6 and extend, at a maximum, 61,000 ft away from the EAA Reservoir A-1 embankment. The cities of South Bay and Belle Glade, FL are at risk in this breach condition as well. The EAA Reservoir A-1 Embankment is a high hazard structure.

7. REFERENCES

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TABLES

Table 1 PMP Breach Results

Scenario	Initial Reservoir Depth (ft)	Breach Width (ft)	Average Failure Speed (ft/s)	Failure Time (hrs)	Max Flow at Dam (cfs)	Distance of 2 ft Limit (ft)	Velocity at 2 ft Limit (ft/sec)	Outflow Velocity At End of Failure Progression (ft/s)	Reservoir Depth At End of Failure Progression (ft)	Floodwave Arrival Time at South Bay, FL (hrs)
1*	16.5	2000	0.05	11.11	163,900	82,100	0.43	6.34	9.95	11
2	12	1500	0.05	8.33	96,700	60,200	0.45	6.61	9.01	12.5
3	16.5	2000	0.55	1	306,400	82,300	0.43	11.33	15.32	7
4	16.5	2000	0.05	11.11	31,700	60,600	0.45	3.13	15.23	NA
5	16.5	2000	0.05	11.11	164,800	65,300	0.47	7.36	9.49	12.25
6	16.5	2000	0.05	11.11	160,800	96,200	0.40	5.56	10.07	10
7	16.5	2000	0.05	11.11	94,000	79,600	0.18	2.63	12.70	20

* Scenario 1 was chosen as the PMP scenario to be used for the Inundation Mapping, see Figure 5 for a pictorial representation of Scenarios 1's results

Note: See Sections 5.2 and 5.3 for descriptions of each scenario

Sunny Day Breach Results

Scenario	Initial Reservoir Depth (ft)	Breach Width (ft)	Average Failure Speed (ft/s)	Failure Time (hrs)	Max Flow at Dam (cfs)	Max Distance of 2 ft Limit (ft)	Velocity at 2 ft Limit (ft/sec)	Outflow Velocity At End of Failure Progression (ft/s)	Reservoir Depth At End of Failure Progression (ft)	Floodwave Arrival Time at South Bay, FL (hrs)
1	12	1500	0.05	8.33	96,678	60,200	0.45	6.61	9.01	12.5

* Scenario 1 was chosen as the Sunny Day scenario to be used for the Inundation Mapping, see Figure 6 for a pictorial representation of Scenarios 1's results

Note: See Section 5.3 for descriptions of this scenario

FIGURES

Figure 1 A-1 Embankment Cross Section

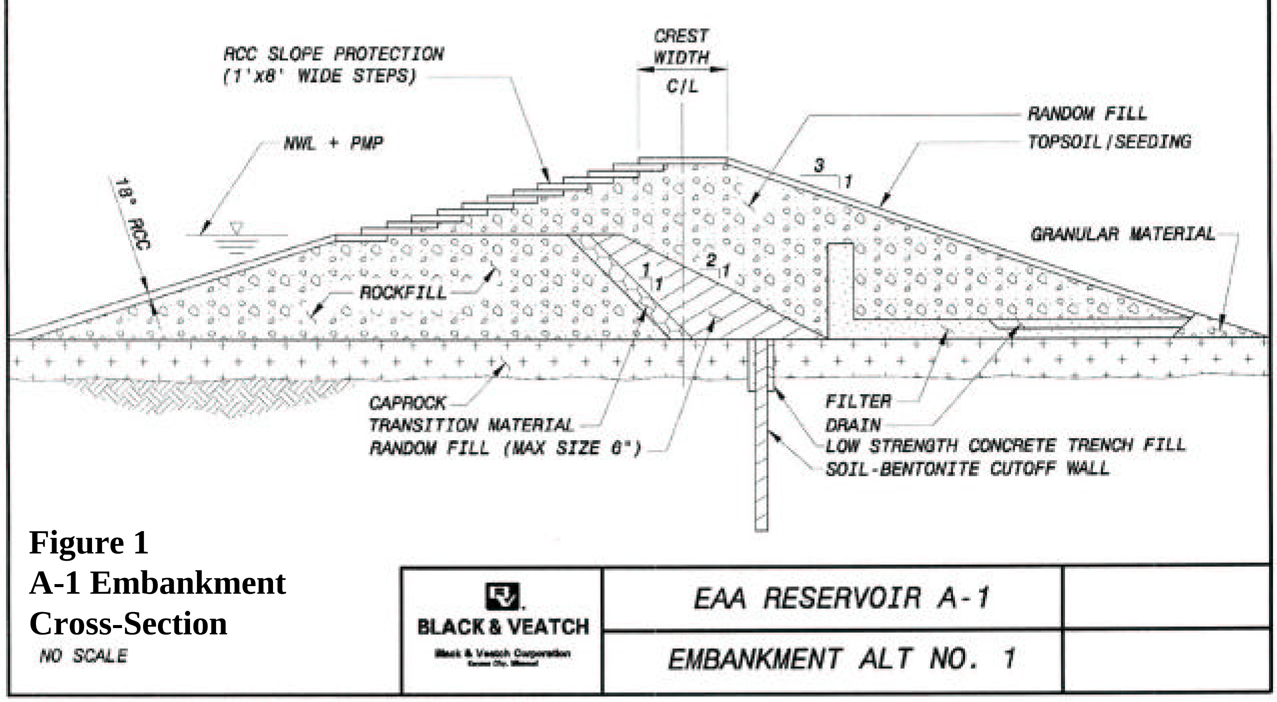


Figure 1
A-1 Embankment
Cross-Section

Figure 2 Bolles Canal Embankment Elevations

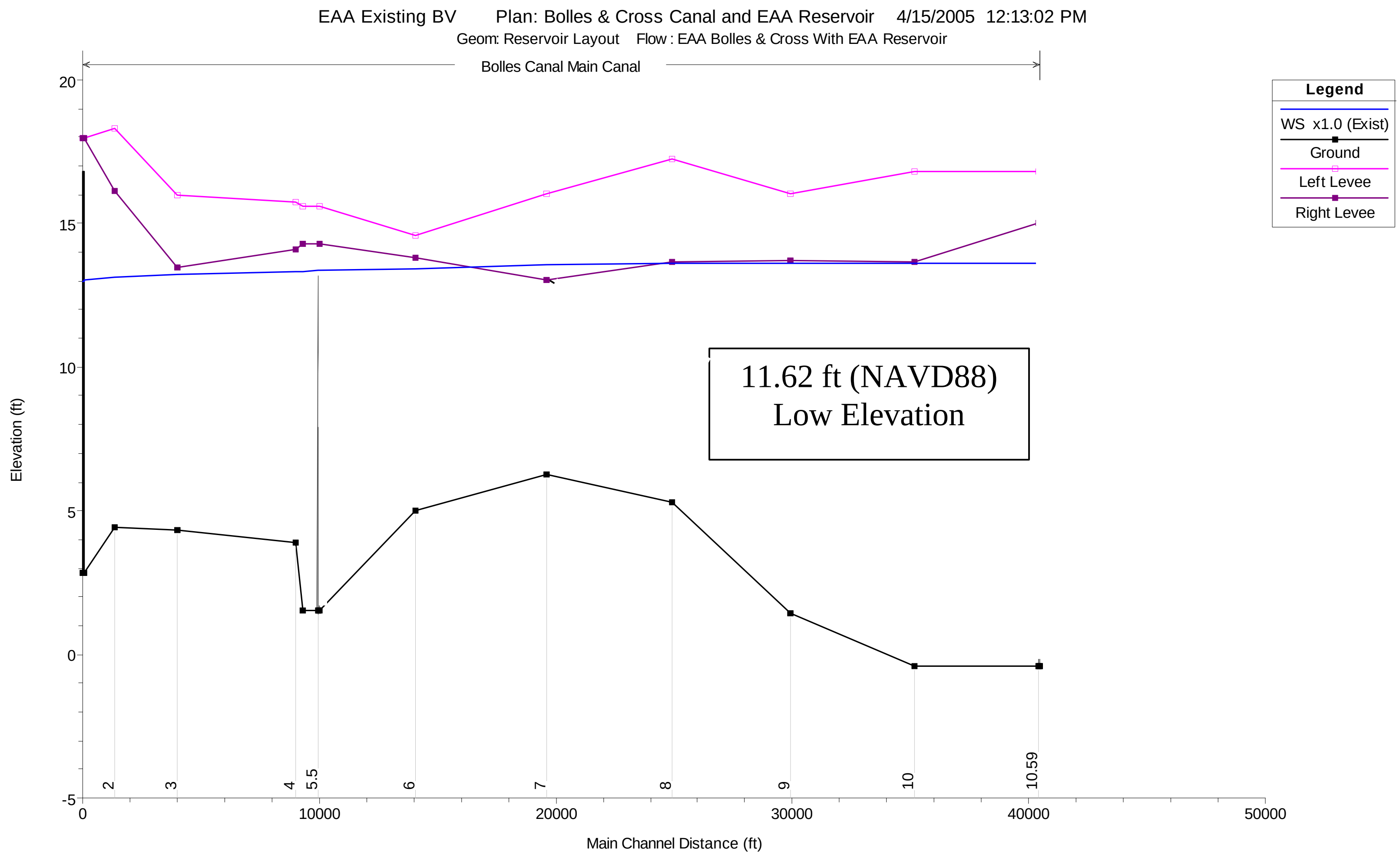
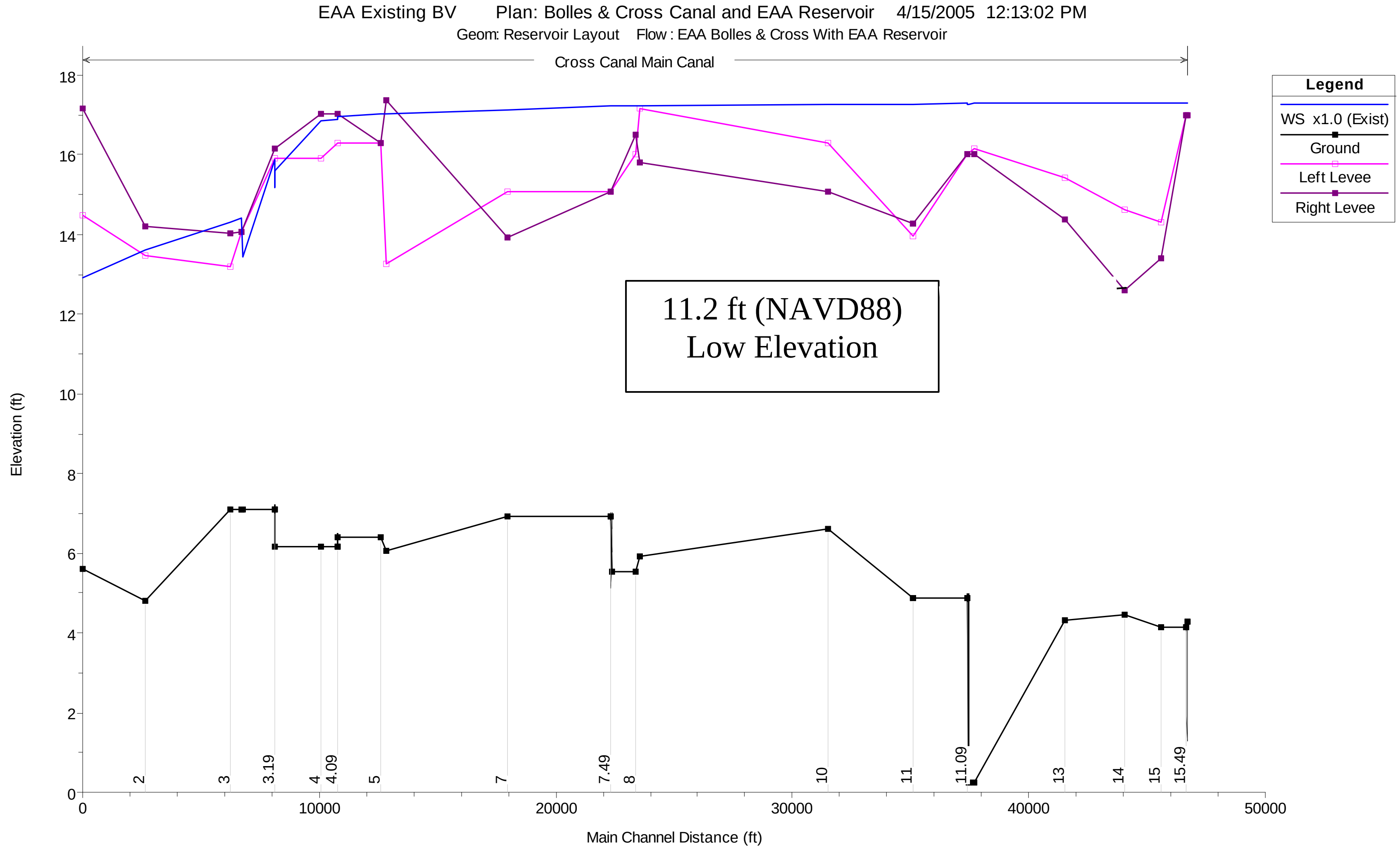


Figure 3 Cross Canal Embankment Elevations



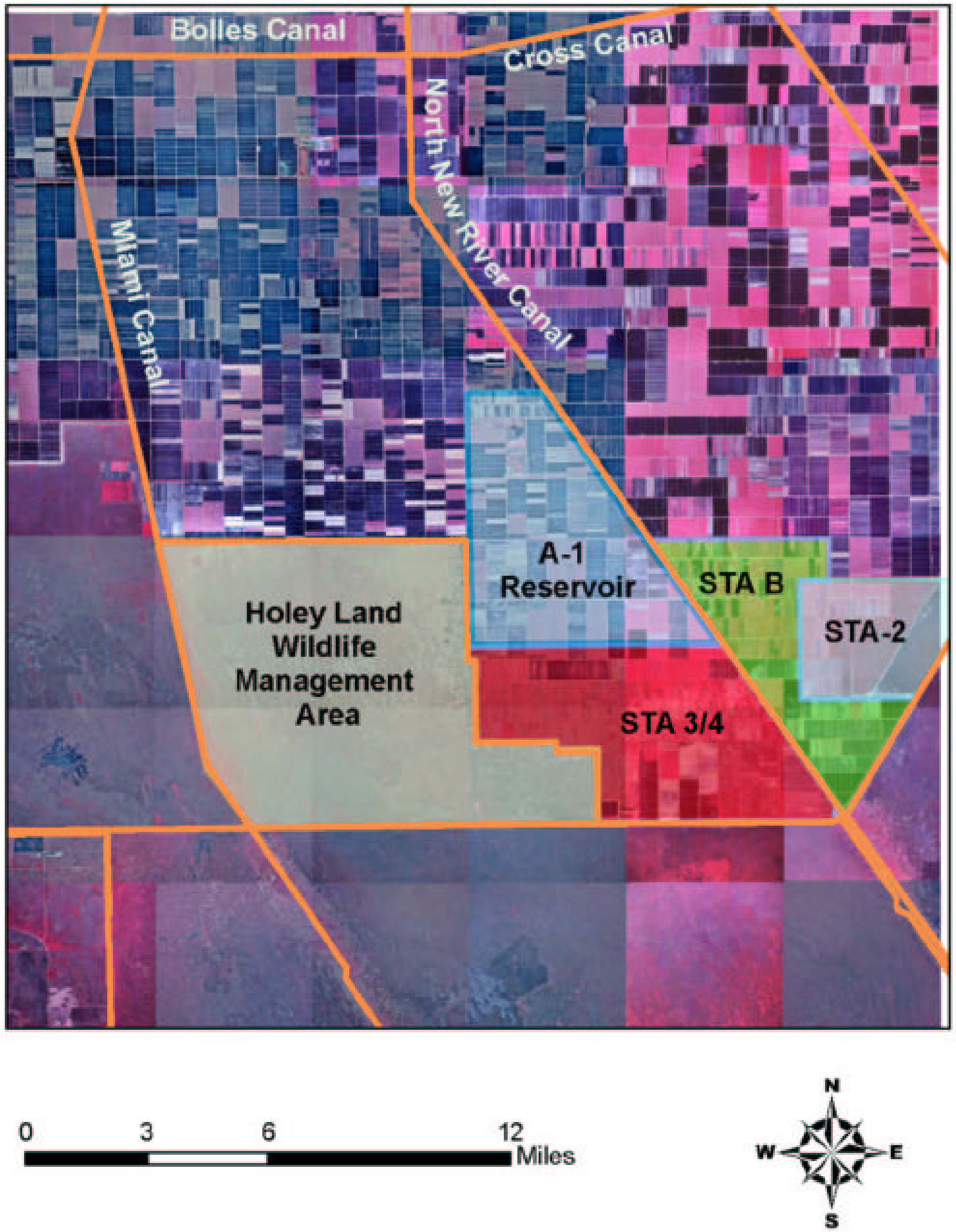
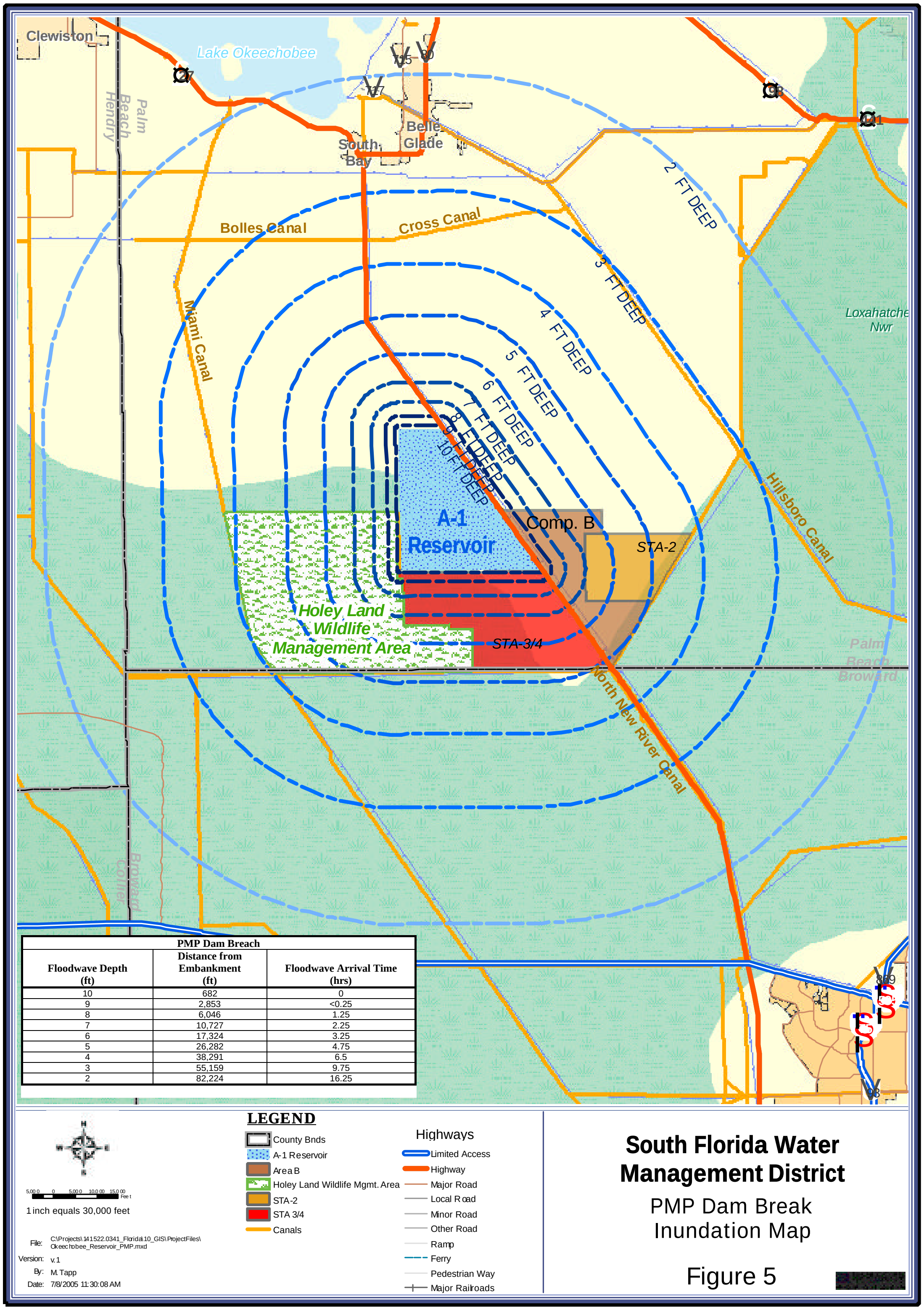


Figure 3 EAA Reservoir Configuration

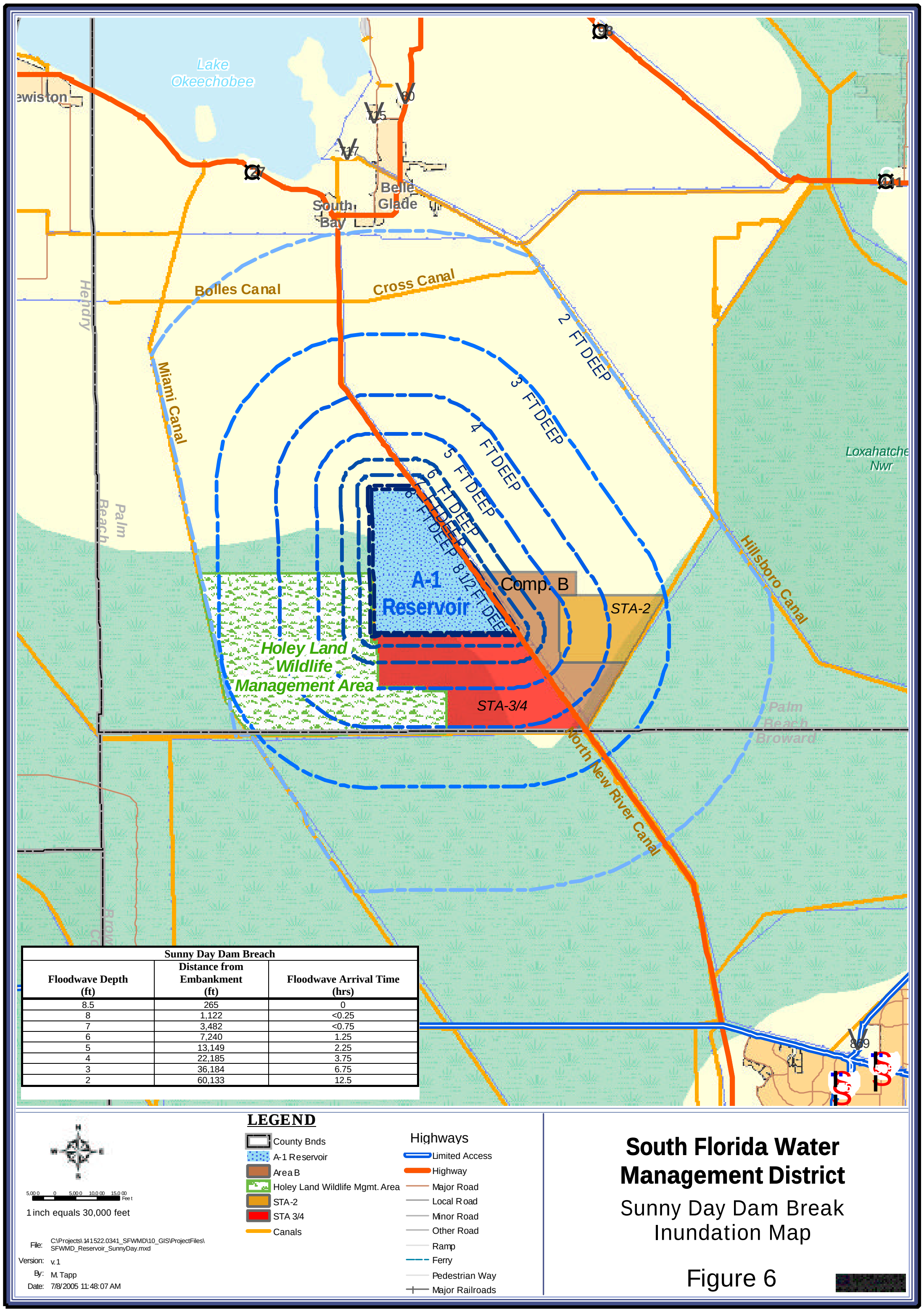
Evaluation of PMP/PMF and Dam Breach

Figure 4 PMP Dam Break Inundation Map



PMP Dam Breach		
Floodwave Depth (ft)	Distance from Embankment (ft)	Floodwave Arrival Time (hrs)
10	682	0
9	2,853	<0.25
8	6,046	1.25
7	10,727	2.25
6	17,324	3.25
5	26,282	4.75
4	38,291	6.5
3	55,159	9.75
2	82,224	16.25

Figure 5 Sunny Day Dam Break Inundation Map



Sunny Day Dam Breach

Floodwave Depth (ft)	Distance from Embankment (ft)	Floodwave Arrival Time (hrs)
8.5	265	0
8	1,122	<0.25
7	3,482	<0.75
6	7,240	1.25
5	13,149	2.25
4	22,185	3.75
3	36,184	6.75
2	60,133	12.5